EXHIBIT A

Excerpts from Streetman, Ben G., Solid State Electronic Device, Prentice-Hall, Inc., 1980, page 67.

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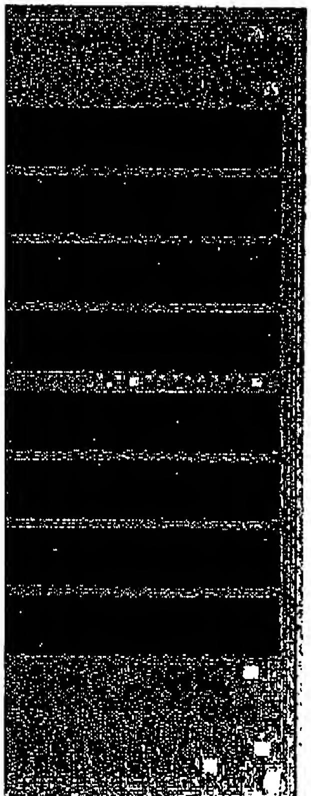

'cuit chip employs charge-coupled
This is achieved with 16 memories of
nip (0.27 cm²). An additional 4 k-bit
als, and peripheral input–output and
modern integrated circuit technology
which cannot be understood without
evices. The purpose of this book is to
er understand and use the solid state
esy of Texas Instruments, Inc.)

SOLID STATE ELECTRONIC DEVICES

second edition

BEN G. STREETMAN

Department of Electrical Engineering
The University of Texas at Austin

a) $d^2\delta p/dx^2 = 0$

1) $d\delta p/dt = 0$

2) $\partial p/\partial t = 0$

b) $0 = D_p d^2\delta p/dx^2 - \delta p/\tau_p + G_L$

rate of diff

c) $d\,\delta p/dt = -\delta p/\tau_p$

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ken away from its position in the bond to move about in the lattice, a conduction bond (hole) is left behind. The band gap energy E_g. This model helps m of EHP creation, but the energy band purposes of quantitative calculation. O bond" model is that the free electron d in the lattice. Actually, the positions e spread out over several lattice spacin mechanically by probability distribution

are created in pairs, the conduction is per cm³) is equal to the concentr les per cm³). Each of these intrinsic ed to as n_i. Thus *for intrinsic material*

$$= p = n_i \quad (3$$

ertain concentration of electron–hole p ier concentration is maintained, there same rate at which they are gene lectron in the conduction band make n empty state (hole) in the valence ba lenote the generation rate of EHP's a tion rate as r_i, equilibrium requires tha

$$r_i = g_i \quad (3$$

dependent. For example, $g_i(T)$ increa d a new carrier concentration n_i is est ination rate $r_i(T)$ just balances generation that the rate of recombination of el equilibrium concentration of electr

$$_0 p_0 = \alpha_r n_i^2 = g_i \quad (3$$

rtionality which depends on the particul n takes place. We shall discuss the calcu ture in Section 3.3.3; recombination p 4.

arriers generated thermally, it is po s by purposely introducing impuriti *oping*, is the most common techniqu

the conductivity of semiconductors. By doping, a crystal can be so that it has a predominance of either electrons or holes. Thus there types of doped semiconductors, n-type (mostly electrons) and p-type holes). When a crystal is doped such that the equilibrium carrier tions n_0 and p_0 are different from the intrinsic carrier concentration material is said to be *extrinsic*.

impurities or lattice defects are introduced into an otherwise crystal, additional levels are created in the energy band structure, within the band gap. For example, an impurity from column V of periodic table (P, As, and Sb) introduces an energy level very near the conduction band in Ge or Si. This level is filled with electrons at 0°K, and little thermal energy is required to excite these electrons to the conduction band (Fig. 3-11). Thus at about 50–100°K virtually all of the electrons impurity level are "donated" to the conduction band. Such an impurity called a *donor* level, and the column V impurities in Ge or Si are called impurities. From Fig. 3-11 we note that material doped with donor impurities can have a considerable concentration of electrons in the conduction band, even when the temperature is too low for the intrinsic EHP generation to be appreciable. Thus semiconductors doped with a significant number of donor atoms will have $n_0 \gg (n_i, p_0)$ at room temperature. n-type material.

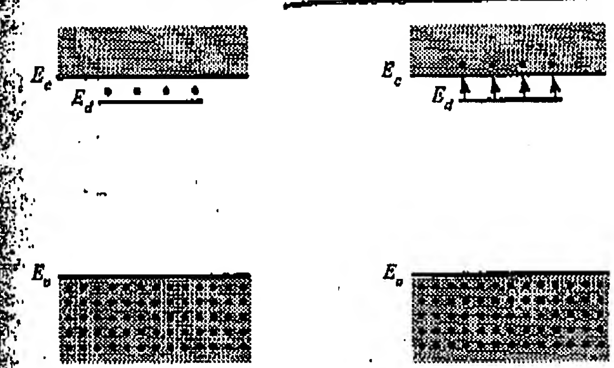

Figure 3-11. Donation of electrons from a donor level to the conduction band.

Atoms from column III (B, Al, Ga, and In) introduce impurity levels in Si near the valence band. These levels are empty of electrons at (Fig. 3-12). At low temperatures, enough thermal energy is available to excite electrons from the valence band into the impurity level, leaving holes in the valence band. Since this type of impurity level "accepts"

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